Shape Defect Detection for Product Quality Inspection and Monitoring System

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***Abstract*— This paper presents an automated computer vision system of shape defect detection for product quality inspection and monitoring system. Soft drink bottle is used as a tested product for the proposed system. The analysis framework includes data collection, pre-processing, morphological operation, feature extraction, and classification. Morphological operation technique is used to segment the image of the bottle via erosion and dilation process. Through this technique, the defect in the bottle structure is described from the feature set such as area, perimeter, major axis length and extend. Then, the bottle is classified either it is pass or rejects from the estimated parameters using Naïve Bayes classifier. The results have proven that the proposed system can be applied to differentiate bottle according to shape with 100% accuracy using 100 samples.**

Keywords—Automatic inspection; Computer vision; Naïve Bayes classifier

I. INTRODUCTION

In an industrial field, it is important to properly manage quality control and quality assurance to achieve company business objective. It is company responsibility to provide high-quality products that follow industry standard operating procedures [1], [2]. In developing a product, all the requirement need to be fulfilled to increase the customer trust and confidence to buy the product. The system based approach has been agreed by industries that it has high efficiency and good in sustainability to increase its operation system [3]. A monitoring system should be implemented in the manufacturing process because of the capability to monitor product consistently and saves time [4].

In previous studies of shape defect detection, Moradi *et al.*, introduces Statistical Histogram Fuzzy C-Means (SH FCM) algorithm to detect apple defects. The experimental results show that SH FCM algorithm contributes to fast processing time compared to conventional FCM [5]. Conversely, studied made by [6], presents a system to inspect defect during glue process using the shape-based matching technique. Three defects are classified which are the main defect, gap defect, bumper defect and bubble defect. From 15 tested images, the proposed method achieves 85% of accuracy.

In the paper by Mu *et al.*, the wood quality become the major concern in wood production. Median filter and Log operator are applied to do edge extraction for the wood image. The results show this study is efficient and reliable to help wood production in order to produce high quality of wood [7].

In [8], an erosion-based method is proposed to classify the shape of the plastic bottle for an automated classification system. This paper compares two methods which are regular erosion and partial erosion. Partial erosion is the upgraded version from the regular version that can set the erosion effect of the image. Both methods achieved more than 80% of accuracy and it is efficient to be applied on the plastic bottle based on shape either slim or broad bottles.

Liu *et al.*, suggests inspection system for film capacitor defect using machine vision to replace the human inspection method that is not efficient to be used in industry. The shape and gradient detection methods are applied to inspect the defect of capacitor surface. After the classification process, the mechanical device will cut off the defective capacitor. The system has met the industry requirement because of the high accuracy, consume less time and efficient in detecting the defect products [9]. The previous techniques are summarized in TABLE I.

The big challenge in production is to get high quality with zero defects of the product. It is because the defects are usually tiny, random defects and irregular shape [10]. Due to the difficulties to inspect the product, human visual inspection has been replaced by automated visual inspection over the last few decades. Manual inspection is prone to human error such as fatigue, sickness, and boredom [11]. Moreover, the human need to be trained as an inspector to apply the skills during the inspection process. Therefore, this paper presents a product quality inspection and monitoring system to detect the shape defect of the bottle.

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TABLE I. SUMMARY OF PREVIOUS RESEARCH

Author	Method	Limitation
Moradi *et al.*	- Fuzzy C-Means (FCM) - Statistical Histogram Fuzzy C-Means (SHFCM)	- Sensitivity to noise. - Difficult to implement in real-time.
Haniff *et al.*	- Shape-based matching template	- Manually set the matching score. Inaccuracy will happen if the score is set too low.
Mu *et al.*	- Median filter - Log operator	- Consume more time to process the algorithm.
Ramli *et al.*	- Regular erosion - Partial Erosion	- Manually set the effect of erosion. All the edges of the bottle are removed if the value is set more than 100%.
Liu *et al.*	- Shape detection - Gradient detection	- Cannot detect a small defect.

In comparison to previous studies, this paper highlights the needs for automatic computer vision system to detect shape defect in the bottle for soft drink productions. Image processing technique and the Naïve Bayes classification algorithms are designed to classify the shape of the bottle. Based on the accuracy of the system, the proposed algorithms are verified using 100 samples. The remainders of the paper are organized as follows. Section I is a background of proposed project. The system principle and methodology is explained in Section II. Section III presents the analysis of the experimental result. Section IV concludes and summarizes the paper.

II. METHODOLOGY

This project is developed using MATLAB as the computational tool for detecting the defect of the bottle's shape. As shown in Fig. 1, the first stage in project development is to get the sample image. A digital camera with high resolution is chosen to capture the image of the bottle. Then, the image will be analyzed using image processing technique. The image processing technique includes the conversion from RGB to Grayscale, thresholding, morphological operation, and segmentation. Followed by feature extraction then classification procedure using Naïve Bayes technique. In a classification operation, collected feature of the shape from multiple images are used to train the network. A set of images are preprocessed and their features extracted with mentioned technique and then, stored in a database so that it can learn and recognize the patterns accordingly. The classification will able to identify the shape of the bottle and hence reject abnormal shape that being fed into the system afterward.

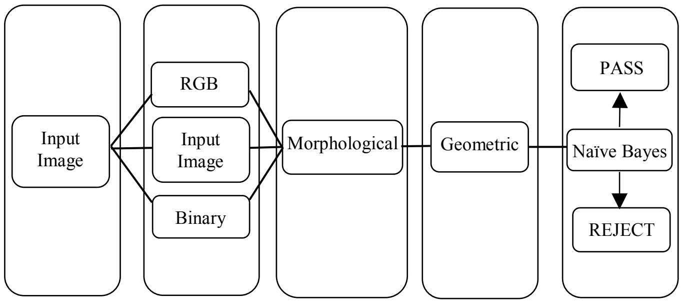


Fig. 1. Analysis framework

A. Image Acquisition

Image acquisition is the process of acquiring an image from source. Hardware setup and equipment also play a very important role in acquiring images with sufficient contrast and sharp focusing. The use of chamber box for image acquisition as illustrated in Fig. 2 will increase the system accuracy with the noise reduction. Nevertheless, this project is stressing on the software framework and a 12-megapixel camera is used as an image acquisition device. MATLAB software is chosen as the development tools. A 12-megapixel camera is used for taking the images of the bottle. The distance between bottle and camera is fixed to 14 cm. The number of pixel presents the height of the bottle. It is important to maintain the position of the camera as the size of image decrease as the distance of camera increase [12].

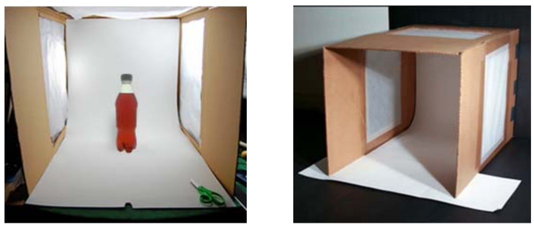


Fig. 2. Chamber box for image acquisition

B. Pre-Processing

Pre-processing is an initial process in image processing technique to improve the quality of the image. The aim of pre-processing is to remove unwanted noise and increase the intensity of the image. By converting the input image into a grayscale color, the complexity in analysis can be reduced.

1) Red Green Blue (RGB) color

The image color is presented in RGB or HSV color space using color vision. For example, image from RGB color space describes the amount of red (R), green (G) and blue (B). Meanwhile, hue (H), saturation (S), and value (V) are described from HSV color space. Fig. 3 shows the conversion of RGB to HSV color model.

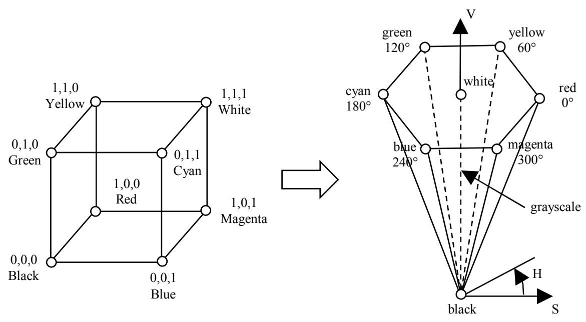


Fig. 3. Conversion of RGB to HSV Color Model

The color type represents by hue is ranged between 0° to 360°. Different color such as red at 0°, yellow at 60° and passing through the green at 120° are placed around the color wheel of the cone (see Fig. 3). In determining the purity of color, saturation is used. It ranges between 0 to 1. An example of green color with the saturation of 0 will appear in white, while saturation of 1 present of pure green color. Opposite from saturation is value. A black is represented by a value of 0, with increasing of lightness towards the top of the cone (value of 1) reached [13], [14].

2) Thresholding

Thresholding is used to separate the image object and background. By assigning an intensity value of T (threshold), an object or background of the image can be classified. The quantization levels of image intensities which are 256 are used to determine the threshold value where weakest intensity level is black while strongest intensity level is white. Therefore, proper wrong selection of threshold value may misinterpret background pixel as an object for classification.

3) Binary Image

To reduce the image processing time, analysis based on the region of interest (ROI) is needed. The image ROI (a portion of the image that is of interest) is determined by converting the image into binary form [15]. This process will create a binary mask where the pixel of 1 is defined as ROI and pixel of 0is an unwanted object.

The ROI of an image has not specified to only one object. More that one ROI can be implemented to determine the geographic in nature such as polygons with a different range of intensities *or* encompass contiguous pixels. In the latter case, the pixels are not necessarily contiguous.

C. Shape Segmentation

An important part of image processing and pattern recognition is segmentation. The segmentation is an important research field and several segmentation methods have been proposed in the literature. Segmentation is a process that divides an image into its region or objects that have similar features or characteristics. Image processing of computer vision in segmentation plays an important role in the first step before applying to image higher-level operations such as recognition, semantic interpretation, and representation.

1) Morphological Operation

The morphological operation technique involved by utilizing the processes of erosion and dilation, opening and closing is a simple extension of these applications. The quality of the images can be increased from the reduction of noise using this technique [16]. In TABLE II, the process of "opening" an image will likely smooth the edges, break narrow block connectors and remove small protrusions from a reference image. While "closing" an image will also smooth edges but will fuse narrow blocks and fill in holes [17]. Overall, they have required an operation that able to bridge gaps and fill holes but don't change the overall size of original image.

TABLE II. APPLICATION OF MORPHOLOGICAL TECHNIQUE

Opening	Closing
A ○ B = (A Y B) D B	A ● B = (A D B) Y B
Erode, then Dilate	Dilate, then Erode
• Break narrow bridges • Eliminate thin structures	• Fuses narrow breaks • Eliminates small holes

The objects that are connected together in binary form is separated during the opening operation. The closing operation can fill in small holes. Both operations generate a certain amount of smoothing on an object contour given a "smooth" structuring element. The opening smooths from the inside of the object contour and the closing smooths from the outside of the object contour.

D. Feature Extraction

The preciseness and accuracy of image classification depend largely on feature extraction. In this project, Area, Perimeter, Major Axis Length, and Extent are extracted from the processed images. Then, all of the extracted features are reported through a feature vector.

Fig. 4 summarize the features that are used within this project where the details for each of them are explained in the following categories. Based on feature listed in Fig. 4, they will help to describe the relevant shape information contained in the bottle image so that the task of classifying the pattern is made easy by a formal procedure.

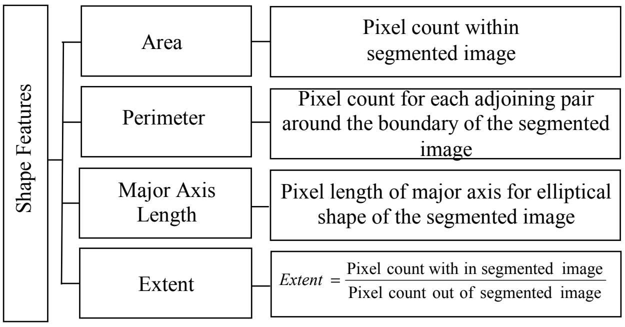


Fig. 4. Feature extraction and its operation on segmented image

E. *Naïve Bayes Classification*

Naive Bayes is a classification technique to solve binary (two-class) and multiclass classification problems in the algorithm. The advantages of Naive Bayes are low in computational complexity and takes a shorter time for the training process. Unlike Neural Networks and Support Vector Machine, they are high in computational complexity and time consuming to process training product [18, 19, 20].

Rather than attempting to calculate the values of each attribute value P(y_1, y_2, y_3|x), they are assumed to be conditionally independent given the target value and calculated as P(y_1|x) * P(y_2|x) and so on. Equation (1) below provides a way of calculating the posterior probability, *P(y|x)*, from *P(y)*, *P(x)*, and *P(x|y)* [21]:

$$P(y\,|\,x) = \frac{P(x\,|\,y).P(Y)}{P(x)} \qquad (1)$$

where:
P (x|y) is the likelihood which is the probability of predictor given class
P (y) is the prior probability of class
P (x) is the prior probability of predictor

III. RESULTS

The Graphical User Interface (GUI) is developed to monitor the system of the bottle shape defect. Fig. 5 and 6 show the layout and complete system design.

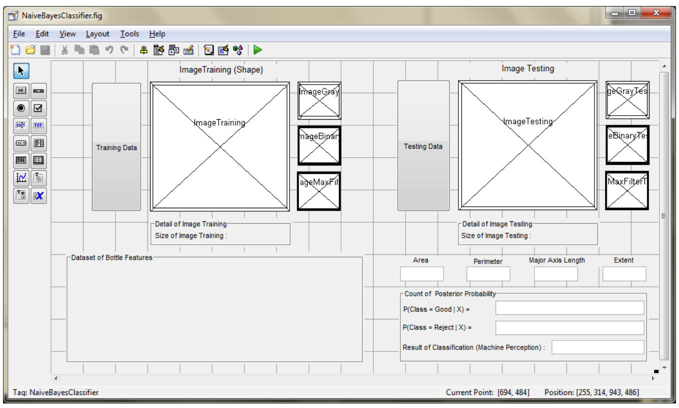


Fig. 5. Graphical user Interface (GUI) layout

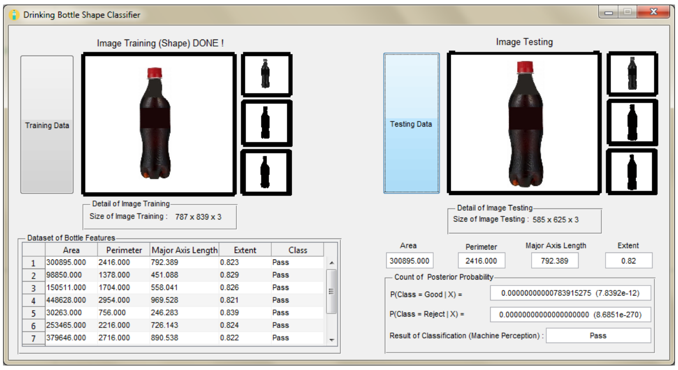
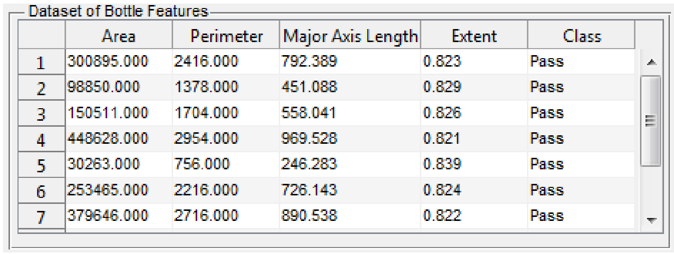


Fig. 6. Graphical user Interface (GUI) of the complete system

Fig. 7 shows the data collected from the bottle features. The features parameters are presented in the form of Area, Perimeter, Major Axis Length, and Extent. The parameter's value is used as the input training for the classifier.



Dataset of Bottle Features

	Area	Perimeter	Major Axis Length	Extent	Class
1	300895.000	2416.000	792.389	0.823	Pass
2	98850.000	1378.000	451.088	0.829	Pass
3	150511.000	1704.000	558.041	0.826	Pass
4	448628.000	2954.000	969.528	0.821	Pass
5	30263.000	756.000	246.283	0.839	Pass
6	253465.000	2216.000	726.143	0.824	Pass
7	379646.000	2716.000	890.538	0.822	Pass

Fig. 7. Dataset of feature extraction

In classifying pass or reject bottle, the expected value and variance of image training of each class are calculated based on statistical probability. Naive Bayes classification is classified pass or rejects bottle depends on the count of the posterior probability value as shown in Fig. 8.

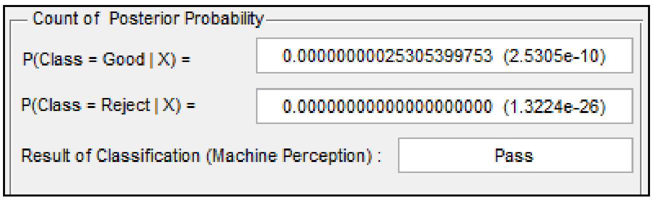


Fig. 8. Naive Bayes classification

Fig. 9 and 10 show GUI of the system based on the shape of the bottle. From the Figure 9, the shape of the bottle is PASS because of the P (class = Good | X) value is higher than P (class = Reject | X) value. Hence, the result of classification is PASS. Vice versa to Figure 10, it shows the shape of the bottle is REJECT due to the P (class = Reject | X) value is higher than P (class = Good | X) value.

The accuracy of the system is illustrated in Fig. 11. For the proposed system, 50 samples are used as a training data and 100 samples are used as a testing data. The system achieved 100% accuracy to classify the shape of the bottle.

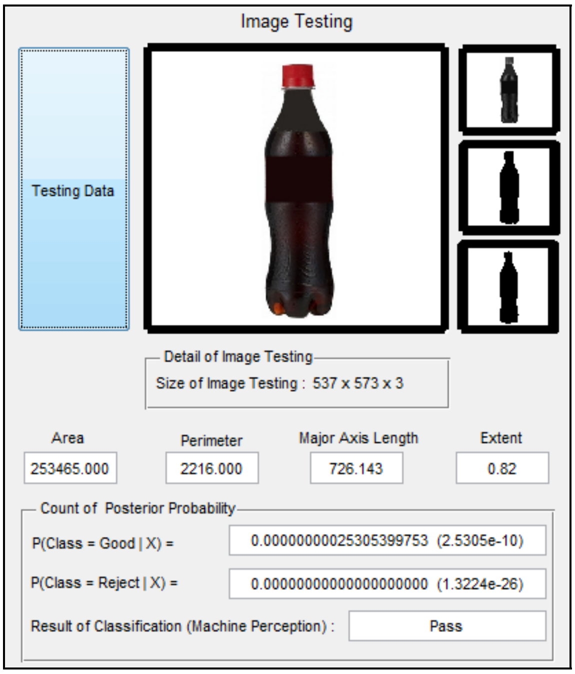


Fig. 9. PASS shape of the bottle

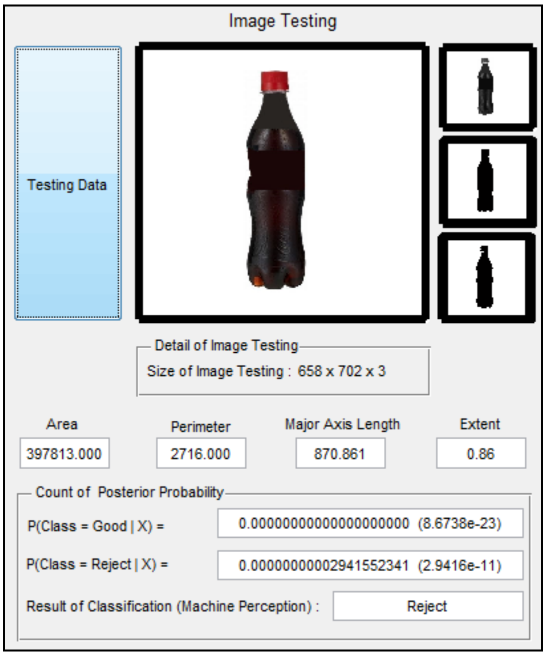


Fig. 10. REJECT shape of the bottle

For the proposed system, 50 samples are used as a training data and 100 samples are used as a testing data. Fig. 11 illustrates the accuracy graph of the shape defect detection system. The accuracy of the system in classifying the shape of the bottle depends on the number of training data. The shape of the bottle is classified using Naive Bayes based on posterior probability value. The system has achieved 100% accuracy to classify the shape of the bottle.

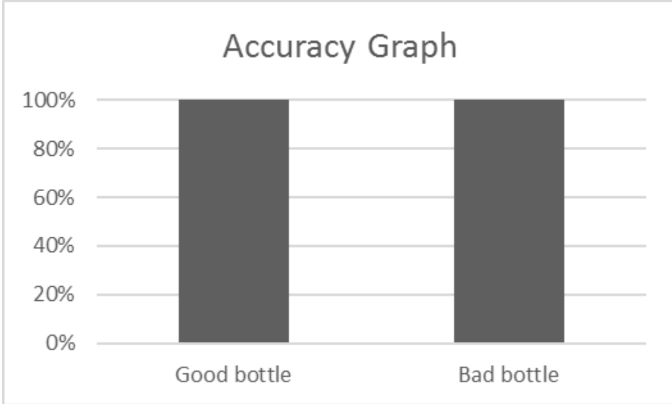


Fig. 11. Accuracy graph of shape defect detection system

IV. CONCLUSION

In conclusion, an automated shape defect detection for product quality inspection and monitoring system is proposed to inspect the shape of the bottle. The system used a Morphological operation that involves erosion and dilation process to segment the bottle. For feature extraction, the parameters such as Area, Perimeter, Major Axis Length, and Extent are extracted from the image. The parameters are used as input to train Naïve Bayes to classify the bottle based on shape, either good or reject bottles. The performance of the system is verified in terms of accuracy. According to the results obtained, 100% accuracy is achieved by using 100 samples image. Hence, the proposed system shows the ability to overcome the issues of quality control by manual visual inspection and high cost for SMEs.

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